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THE THEORY AND USE OF REGIONAL CLIMATE MODELS
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CORDEX South Asia: Overview and Performance of Regional Climate Models

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Centre for Climate Change Research (CCCR)

A Centre for Climate Change Research has been established by the Ministry of Earth Sciences (MoES), Government of India in the Indian Institute of Tropical Meteorology (IITM), Pune to better understand the Science of Climate Change over the tropics in general and the Indian region in particular to enable improved assessments of regional climate responses to global climate change.

Questions : On Attribution?

- How much of the observed variability of the mean Indian Summer Monsoon rainfall due to Climate Change?
- How much of the observed increase in temperature over India been decreased by increasing presence of aerosols?

Questions : On Projections of Monsoon

- What will happen to the monsoon hydrological cycle 50-100 years from now under different scenarios? In particular, will the quantum of seasonal mean rainfall increase or decrease and if so by how much?
- What is the uncertainty in these projections? Can we quantify this uncertainty?
- How can we reduce this uncertainty?

Goals

- *Development of a high resolution Earth System Model to address issues on Attribution and Projection of regional climate change*

- *Generation and communication of reliable inputs for impact assessment studies*

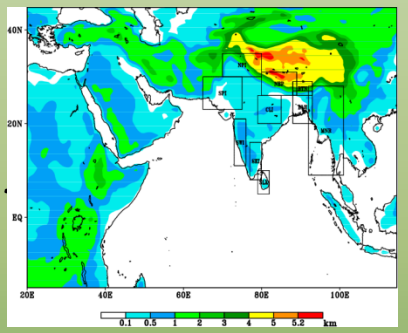
- *Establishment of observational monitoring networks*

CORDEX South Asia Co-ordination

Role of CCCR-IITM and Partners

Co-ordinator: Dr. R. Krishnan, CORDEX Science Advisory Team (SAT) Member &
Executive Director, CCCR-IITM

- **Development of multi-model ensemble projections of high resolution regional climate change scenarios for CORDEX South Asia**
  - Generation of regional climate projections at CCCR-IITM
  - Co-ordination with partner institutions for multi-model ensemble projections – SMHI, IAES, ICTP, CSIRO, BCCR…



  - **Development of an Earth System Grid (ESG) node at CCCR-IITM for CORDEX South Asia**
  - Archival, Management, Retrieval, Dissemination of CORDEX South Asia data
  - **Evaluation of regional climate projections over South Asia to provide relevant and reliable regional climate change information for effective harnessing of science-based climate information by Vulnerability, Impact & Adaptation (VIA) community**
  - e.g., Regional Climate Model Evaluation System (RCMES), JPL, NASA, USA
  - International Conference on Regional Climate (ICRC) CORDEX 2013, Brussels, Belgium

CORDEX South Asia Co-ordination

Role of CCCR-IITM and Partners

•Development of regional capacity for assessment of regional climate change

- A series of 3 CORDEX training workshops was proposed to be held in South Asia, East Asia and South East Asia during 2013, 2014 and 2015
- Foster synergies and coherence between the various climate downscaling and VIA user communities in Asian region through direct user engagement
- Workshops to be of scientific in nature, covering the state-of-the-art climate downscaling research, training and capacity building
- A bottom-up approach involving participants in the formulation of key science and VIA questions

❖The 1st WCRP CORDEX South Asia Training Workshop in partnership with CCCR-IITM,START,ICTP,CSAG,SMHI & ICSU-ROAP was held at IITM, Pune,India, 17–20 October 2012

(http://cccr.tropmet.res.in/workshop/oct2012/index.html)

❖The 2nd WCRP CORDEX Science and Training Workshop in South Asia In partnership with WCRP-CORDEX, MAIRS, APN, ICIMOD, CCCR-IITM & IAP was hosted by ICIMOD, Kathmandu, Nepal, 27 – 30 August 2013

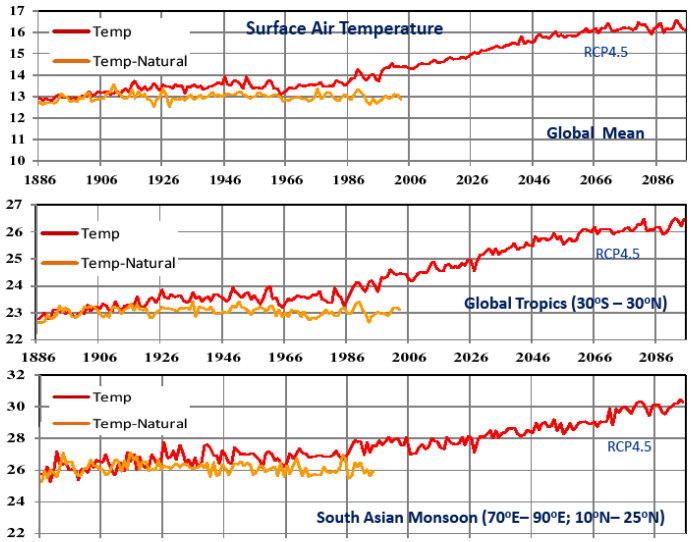
(http://cccr.tropmet.res.in/workshop/cordex2013/index.jsp)

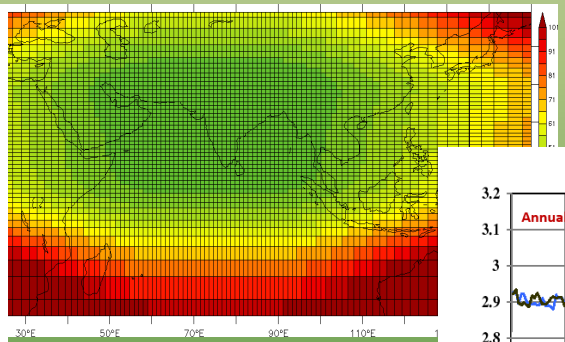
Co-ordinated Regional Downscaling Experiment (CORDEX): South Asia

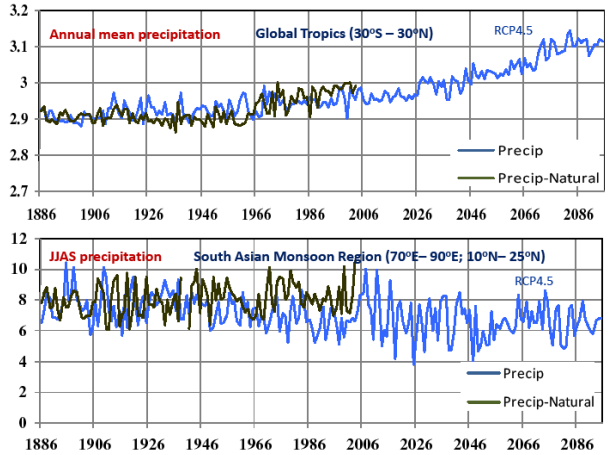
Multimodel Assessment of Regional Climate Change: PRECIS (~ 50 km); WRF (~ 50 km); RegCM (~ 50 km); LMDZ (~ 35 – 50 km); Models from Partner Institutions

LMDZ: High resolution zooming (~35–50 km) over CORDEX domain

- Historical run (1886– 2005): Includes natural and anthropogenic (GHG, aerosols, land cover etc) climate forcing during (1886 – 2005) ~ 120 years
- Historical Natural (1886-2005): Includes only natural climate forcing during (1886– 2005) ~ 120 years
- RCP4.5 (2006-2100): Future projection run including both natural and anthropogenic forcing based on the IPCC AR5 RCP 4.5 climate scenario. The evolution of GHG and anthropogenic aerosols in RCP 4.5 scenario produces a global radiative forcing of + 4.5 W m^{-2} by 2100







Source: Sabin, CCCR

CORDEX South Asia data (50km) is available on the CCCR-IITM Climate Data Portal :
http://cccr.tropmet.res.in/cordex/files/downloads.jsp

CORDEX-South Asia Multi Models Output

Historical (1950 - 2005) | Evaluation Run (1989 - 2008) | RCP 4.5

Variable name (Monthly and Daily)	SMHI-RCA4	IITM-RegCM4-GFDL	IITM-RegCM4-LMDZ	COSMO-CLM	IITM-LMDZ
Institute's / Data Providers	Rossby Centre, SMHI	CCCR-IITM, Pune	CCCR-IITM, Pune	Goethe Inst - Univ. of Frankfurt	CCCR-IITM, Pune
Rainfall (pr)	✓	✓	✓	✓	✓
Surface Air Temperature (tas)	✓	✓	✓	✓	✓
Surface Air Temp. Maximum (tasmax)	✓	✓	✓	--	✓
Surface Air Temp. Minimum (tasmin)	✓	✓	✓	--	✓
Sea-level Pressure (psl)	✓	✓	✓	--	✓
Surface Specific Humidity (huss)	✓	✓	✓	--	✓
Surface Zonal Wind (uas)	✓	✓	✓	--	✓
Surface Meridonial Wind (vas)	✓	✓	✓	--	✓
Downward Shortwave Radiation (rsds)	--	✓	✓	--	--

To download the data please click here

Regridding script example, click here to download | script

CORDEX Regional Climate Models Performance in Present-day Climate for South Asia

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[2]Joint Institute for Regional Earth System Science and Engineering (JIFRESSE), University of California, Los Angeles (UCLA), USA
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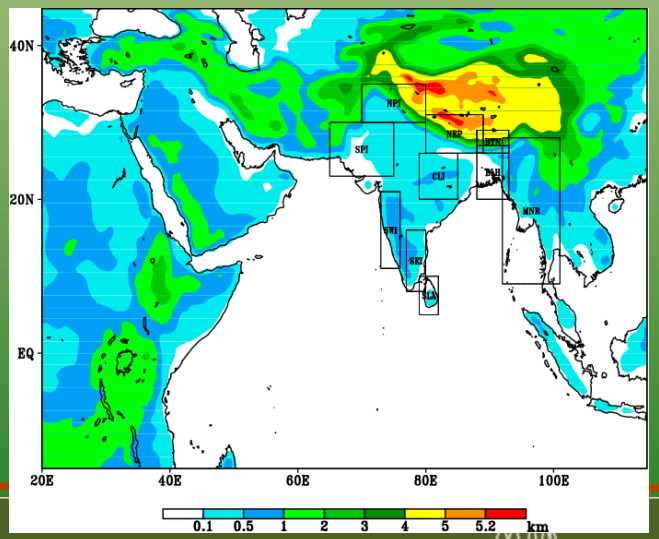
[5]Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy
[6]Jet Propulsion Laboratory (JPL), California Institute of Technology, Pasadena, California, USA
[7]World Climate Research Program (WCRP), World Meteorological Organization (WMO), Geneva, Switzerland

ICRC CORDEX 2013 (http://cordex2013.wcrp-climate.org/posters/P3_27_Sanjay.pdf)

- **The performances of the RCMs participating in the CORDEX South Asia evaluation & historical experiments is evaluated in comparison with those of the AOGCMs participating in the fifth phase of the Coupled Models Intercomparison Project (CMIP5) to facilitate multi-model intercomparison over South Asia**

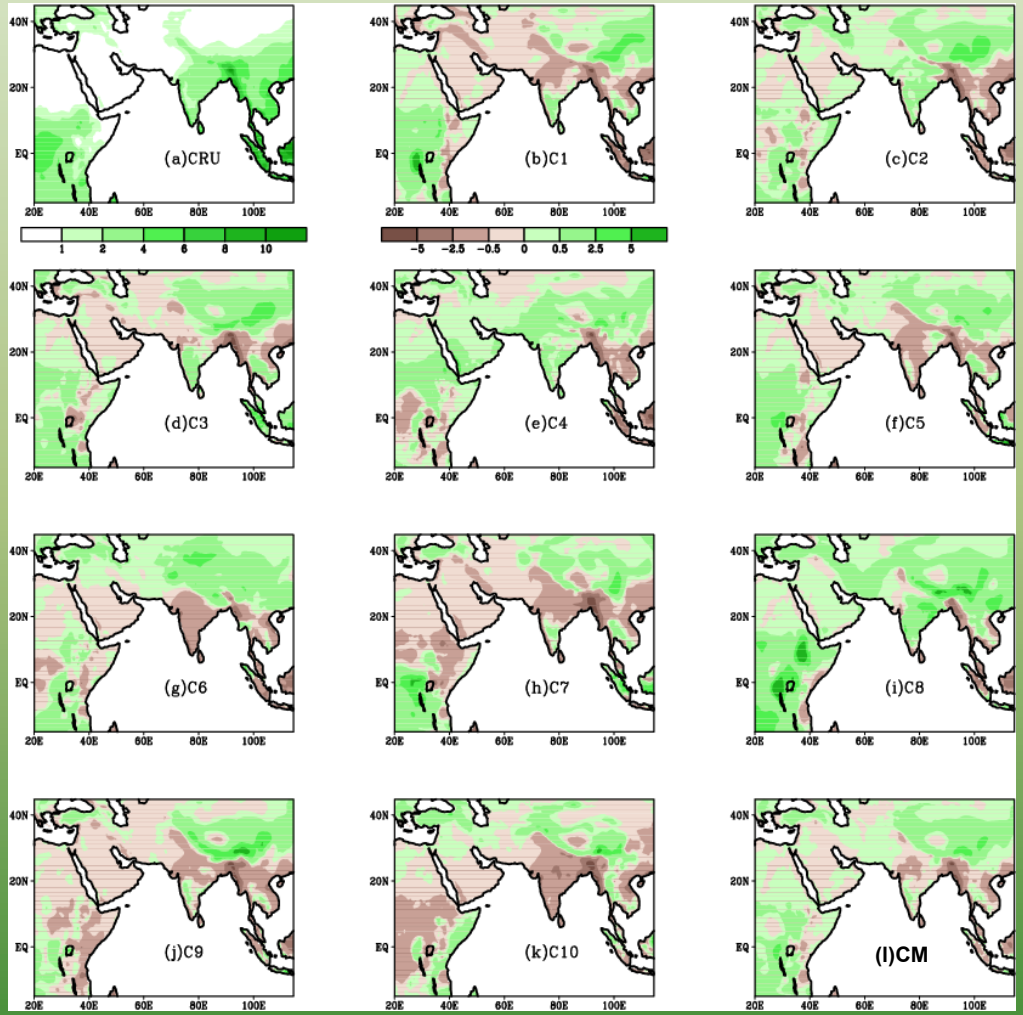
  - Ten CMIP5 AOGCMs & five RCMs are assessed for a common 15-year evaluation period (1990-2004) using the Regional Climate Model Evaluation System (RCMES) tool from NASA JPL, USA, by validating the model simulations with the monthly mean rain gauge-based global land precipitation dataset available at 0.5° spatial resolution from the Climatic Research Unit (CRU) at the University of East Anglia.

Topography (km) over the domain used for the CORDEX South Asia RCM simulations with 0.44° horizontal resolution.



The biases in CMIP5 simulated annual-mean precipitation (mm d^{-1}) for 1990-2004 against the CRU data

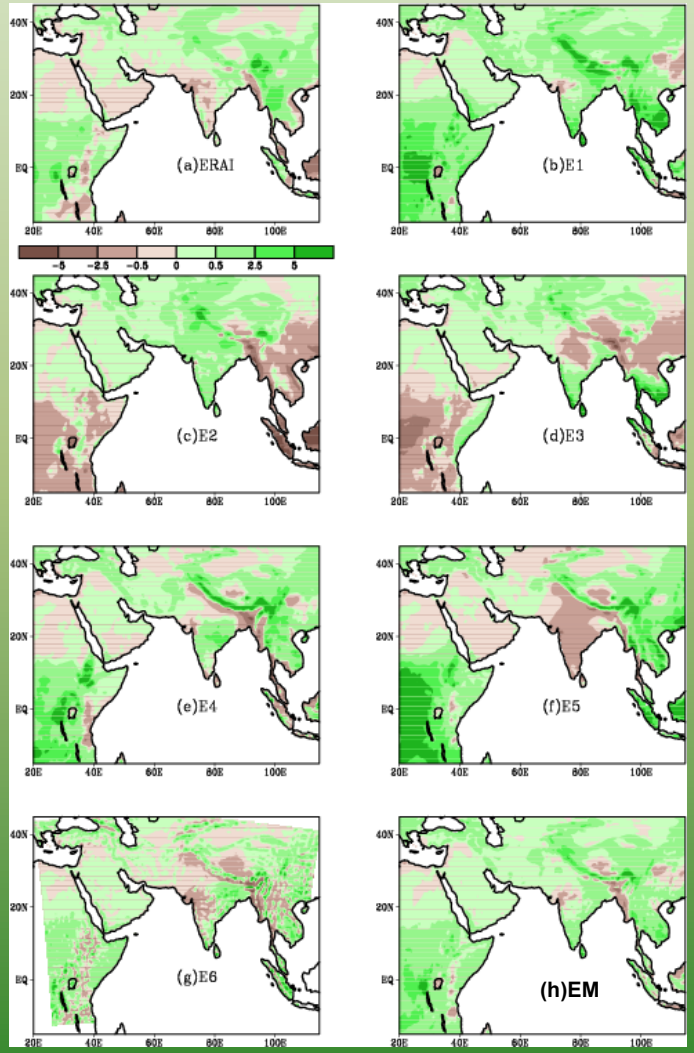
Observed Climate



Model Label	CMIP5 AOGCM Name	Resolution (Lat X Long°)
C1	CanEsm2	2.8° X 2.7°
C2	GFDL-CM3	2.5° X 2.0°
C3	GFDL-ESM2M	2.5° X 2.0°
C4	EC-EARTH	1.125° X 1.125°
C5	HadCM3	3.75° X 2.5°
C6	HadGEM2-ES	1.875°X 1.25°
C7	IPSL-CM5A-LR	1.875°X 3.75°
C8	MIROC5	1.4°X 1.38°
C9	MPI-ESM-LR	1.875° X 1.865°
C10	MRI-CGCM3	1.125°X 1.121°

- The simple statistical (zeroth order) downscaling of the coarse resolution CMIP5 AOGCMs indicate dry bias over central & northern parts of India in most models.
- Three models C2, C4 & C8 tend to show wet bias over this region.
- The overall spatial distribution of the annual mean precipitation climatology is depicted relatively better in the ensemble mean (CM).

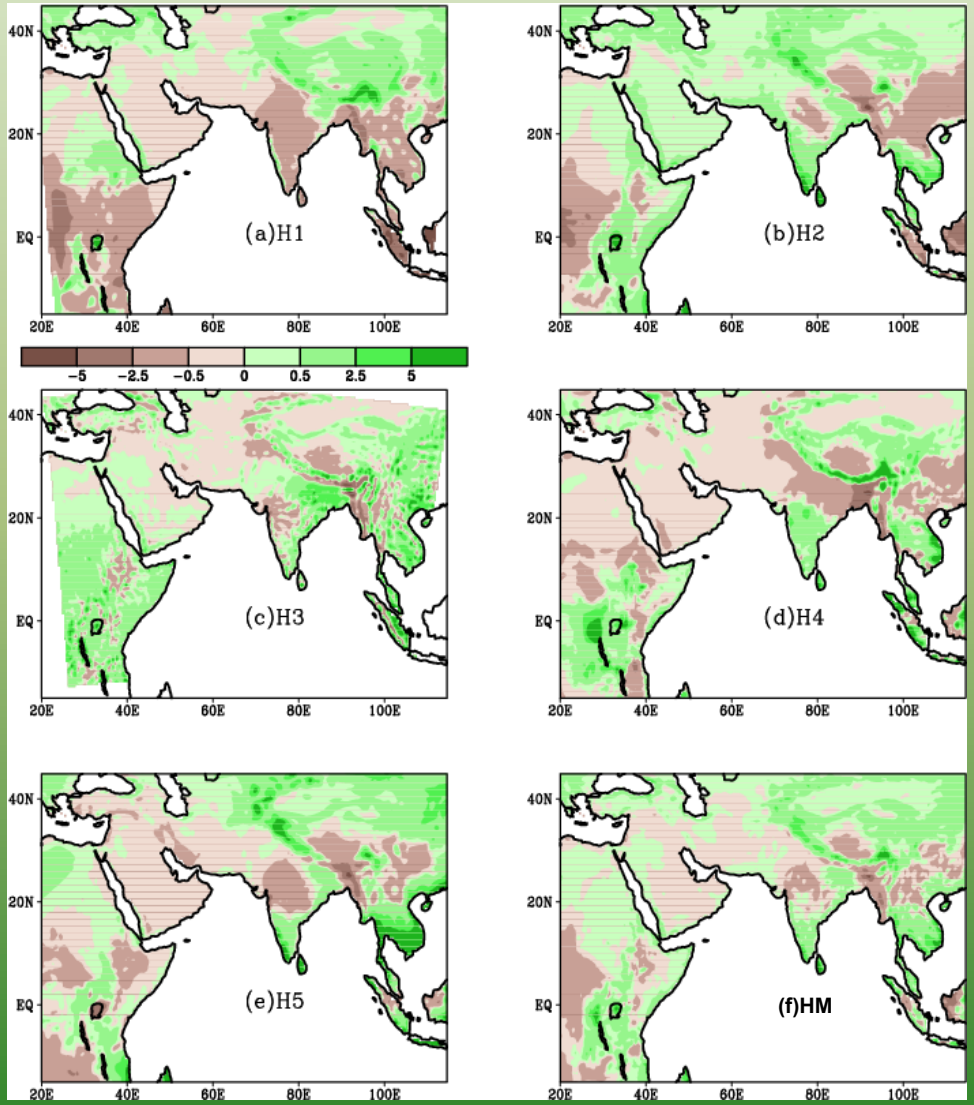
The biases in simulated annual-mean precipitation (mm d^{-1}) for 1990-2004 against the CRU data for the CORDEX South Asia RCM evaluation experiments driven with the ECMWF Reanalysis Interim (ERAI)



Model Label	Contributing Institute	Model Name & Version	Cumulus scheme
E1	IITM	ICTP-RegCMv3	Emanuel
E2	IITM	ICTP-RegCMv3	Grell
E3	IITM	ICTP-RegCMv4.1	Grell (land) & Emanuel(ocean)
E4	IITM	NCAR-ARWv3.1	Betts-Miller-Janjic
E5	IITM	NCAR-ARWv3.1	Kain-Fritsch
E6	SMHI	SMHI-RCAv4	Kain-Fritsch

- ERAI indicates slightly larger dry bias over the peninsular & western parts of India (Fig.a) than the CMIP5 ensemble mean
- The 3 versions of the ICTP-RegCM RCM (E1, E2 & E3), mainly differing in the choice of the parameterization of deep cumulus convection, shows that the model bias changes from wet to dry over central India.
- Two different cumulus schemes in the NCAR ARW RCM (E4 & E5) also brings out the large sensitivity of the physics to the simulated annual precipitation.
- However the ensemble mean (EM) of these 6 RCMs show relatively lesser dry bias over Indian region (Fig. h) than the CMIP5 ensemble mean

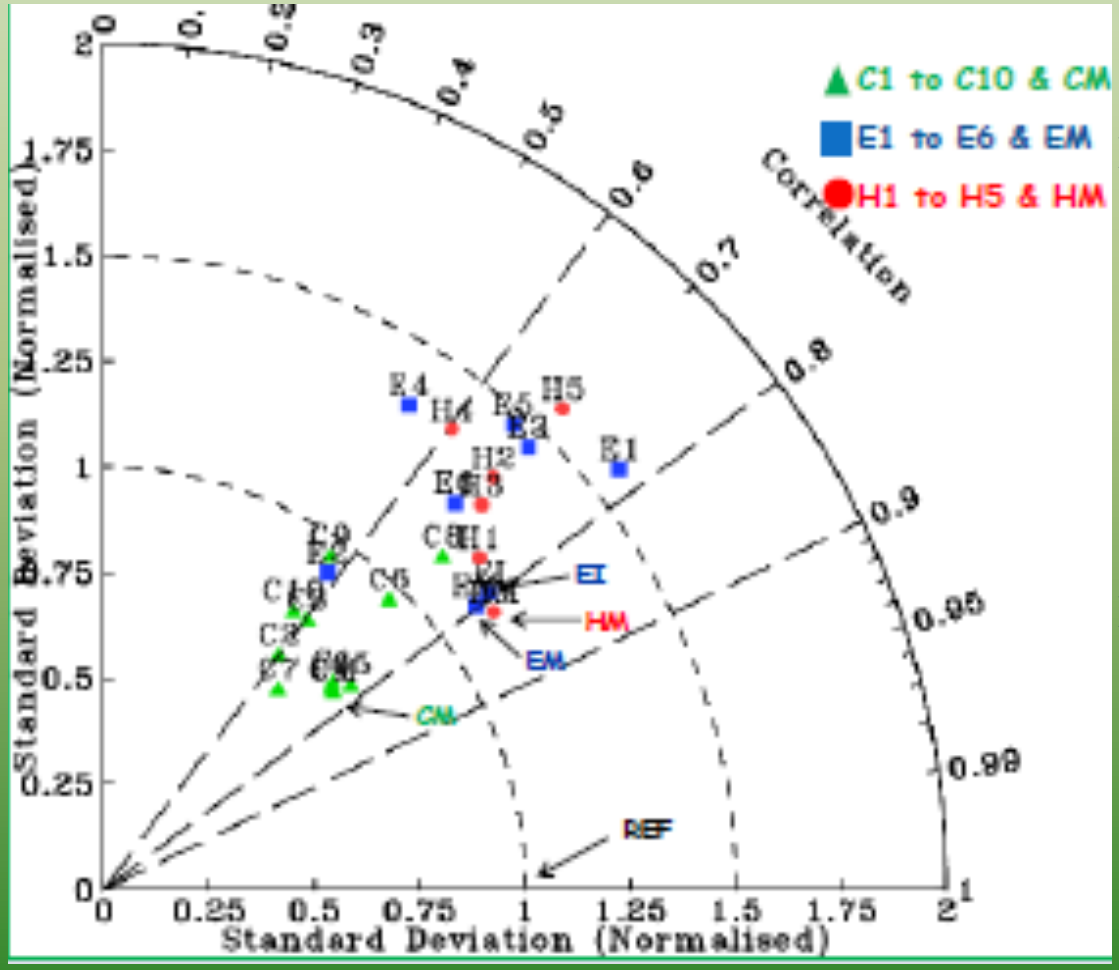
The biases in simulated annual mean precipitation (mm d^{-1}) for 1990-2004 against the CRU data for CORDEX South Asia RCM historical simulations driven with CMIP5 AOGCMs



Model Label	Contributing Institute	Model Name & Version	Driving CMIP5 AOGCM
H1	IAES	COSMO CLM	(C9) MPI-ESM-LR
H2	IITM	ICTP RegCMv4.1	(C3) GFDL-ESM2M
H3	SMHI	SMHI RCAv4	(C4) EC-EARTH
H4	IITM	IPSL LMDZv4	(C7) IPSL-CM5A-LR
H5	IITM	H2	H4

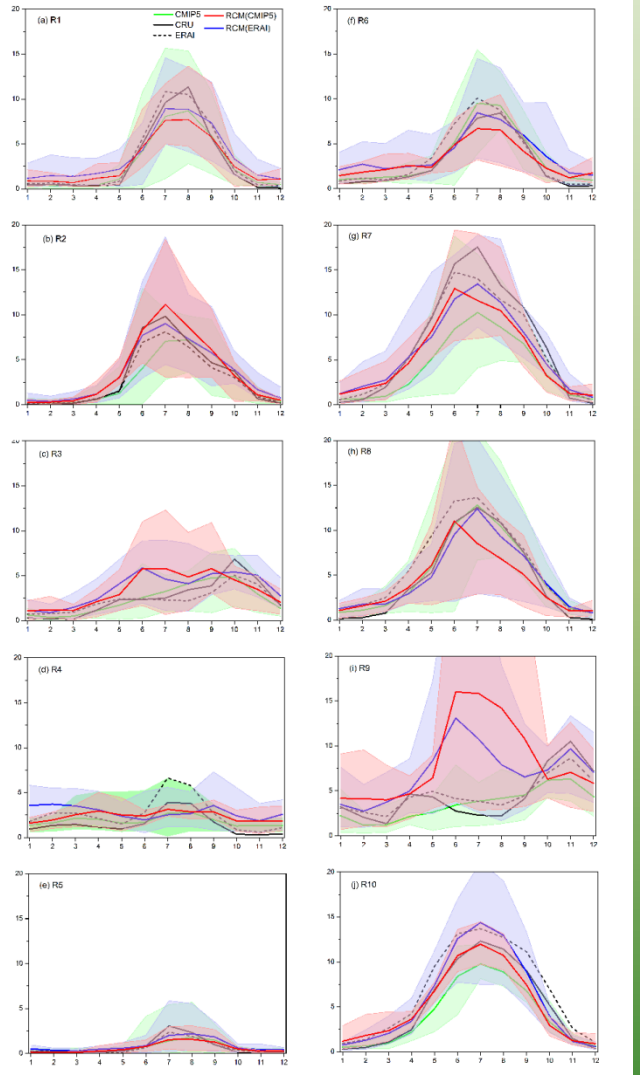
- The individual RCM bias vary from dry to wet over central India in the historical simulations: H1 (Fig. a) to H4 (Fig. d)
- The spatial distribution of the bias is similar for the two simulations H2 (Fig.b) & H5 (Fig.e) with the ICTP RegCM RCM driven with different global models (C3 & H4)

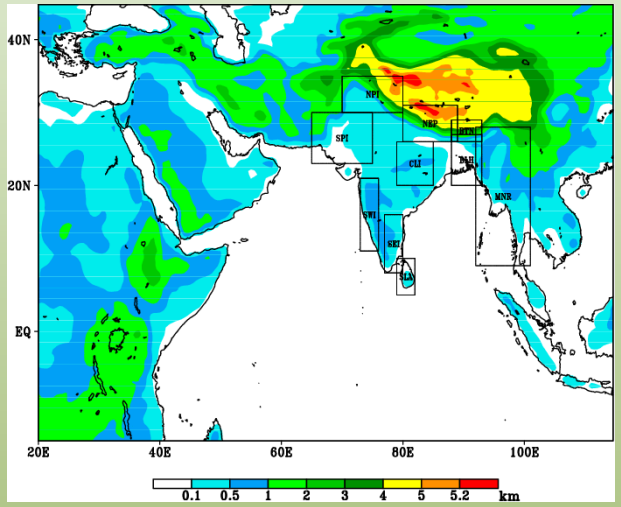
Taylor diagram showing the spatial correlation & standardized deviations in the simulated annual-mean precipitation for all models with reference to CRU data (REF) over the South Asian land area [60°E–100°E & 5°N–35°N].



- The AOGCMs (green triangles) & RCMs (blue rectangles & red circles) show similar skill in simulating the spatial patterns of the observed (CRU) annual precipitation climatology over South Asia.
- However the RCMs overestimate the observed spatial variability.

The simulated precipitation annual cycle (PAC) for 1990-2004 in 10 selected sub-regions over South Asia

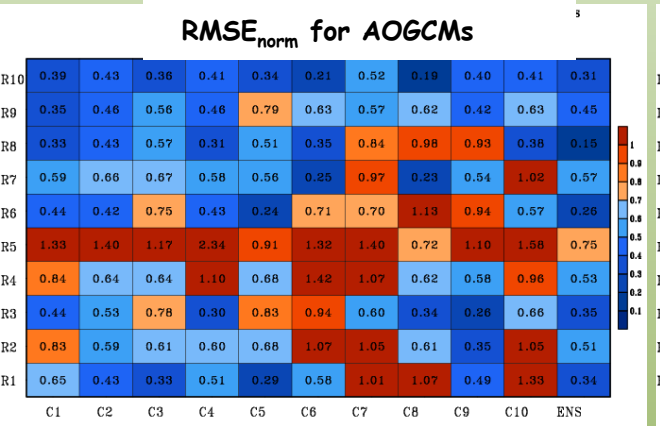


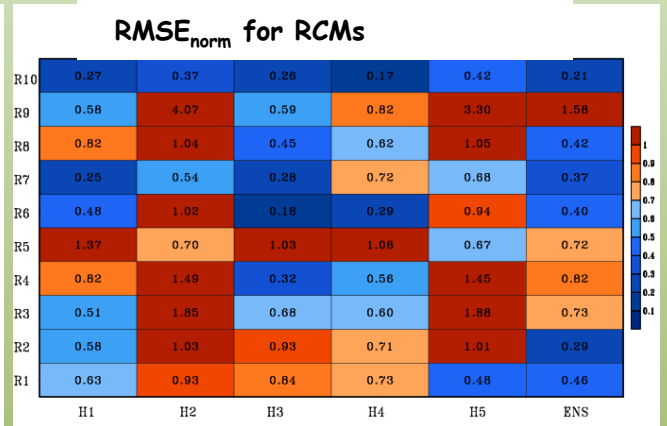


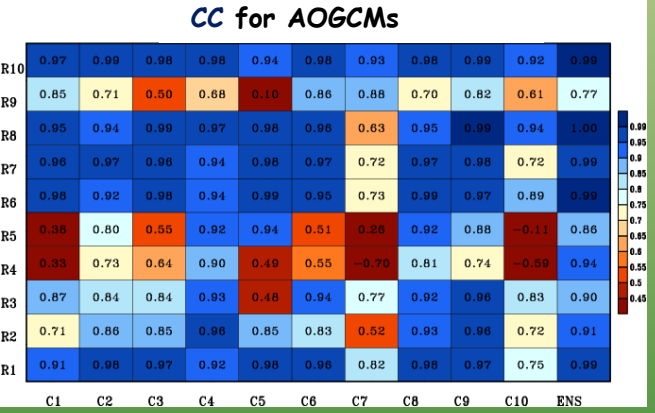
Label	Sub-regions shown as boxes in Figure
R1	Central India (CLI)
R2	South West India (SWI)
R3	South East India (SEI)
R4	North Pakistan & India (NPI)
R5	South Pakistan & India (SPI)
R6	Nepal (NEP)
R7	Bangladesh (BLH)
R8	Bhutan (BTN)
R9	Srilanka (SLA)
R10	Myanmar (MNR)

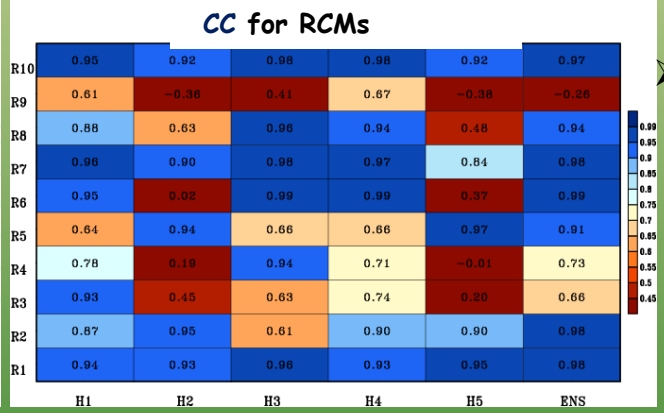
The ensemble mean (thick lines) & the range (shading) for AOGCMs (green), RCMs driven with ERAI (blue) & RCMs driven with AOGCMs (red) are shown. The CRU observations (black line) & ERAI (black dashed line) are also plotted.

The AOGCMs & RCMs skill in simulating the amplitude & phase of PAC with respect to the CRU data is summarized for all sub-regions using portrait diagrams of Root mean square error normalized by CRU annual-mean ($RMSE_{norm}$) & Correlation Coefficients (CC)









Model Label	Model Description	CMIP5 Driving Model
H1	COSMO CLM	(C9) MPI-ESM-LR
H2	ICTP RegCMv4.1.1	(C3) GFDL-ESM2M
H3	SMHI RCAv4	(C4) EC-EARTH
H4	IPSL LMDZv4	(C7) IPSL-CM5A-LR
H5	Same as for H2	(H4) LMDZ AGCM

- 3 RCMs: H1 (CLM), H3 (RCA4) & H4 (LMDZ) indicate improved skill in simulating the PAC amplitude & phase over R6 (NEP), R7 (BLH), R8 (BTN) & R10 (MNR) relative to their driving AOGCMs: C9, C4 & C7.

Summary

- Most AOGCMs & RCMs show significant biases in simulating the main features of the annual precipitation climatology over the South Asia

- However dynamical downscaling of AOGCM outputs using RCMs to the scale more suited to end-users appears to be more useful for understanding local monthly precipitation climate in regions that have complex topography such as Nepal, Bangladesh, Bhutan & Myanmar.

Thanks for your attention

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Thank You

- ICTP Workshop Organisers
- WCRP CORDEX
- CCCR, IITM